**METRIC DEVELOPMENT FOR
CONTINUOUS PROCESS IMPROVEMENT**

THESIS

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AFIT/OR-MS/ENS/11-04

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Abstract

Air Force Smart Operations for the 21st Century (AFSO21) is not currently being used as effectively as it could be across the Air Force. Instead of trying to simply save money here or cut man-hours there, AFSO21 tools should be used to help the Air Force "fly, fight and win" *better*.

The Air Force Institute of Technology (AFIT) has developed a methodology to identify specific target areas where continuous process improvement, i.e., AFSO21, can be applied to improve the bottom line of an organization. The first step of this process is to solicit the key performance indicators (KPIs) that best reflect the organization's mission. The second step is to use and/or develop metrics based on those KPIs to measure the organization's mission performance today. The third step is to capture the trends of those KPIs over time to see if the organization is getting better or worse. The final step is to identify the largest performance capability gaps in order to determine where AFSO21 resources should be applied to get "the most bang for the buck".

The result of this process should give the decision maker the ability to improve the bottom line of an organization by improving its weakest areas. Air Combat Command is used as a case study for the application of this methodology.

Acknowledgments

First and foremost, I want to express my sincere appreciation to my lord and savior Jesus Christ for his daily guidance, motivation, and restoration. Without his leadership, I would not have made it through this grueling program.

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I owe endless thanks to Capt Jimmy Springston for always being one step ahead and taking the time to keep me afloat. A special thanks to Capt Brandon Bernardoni for his continued moral and spiritual support from day one through the end.

I would like to thank my faculty advisor, Dr. Jeff Weir, for his insight and guidance throughout the course of this thesis effort.

I would also like to thank my sponsor, Ms. Melanie DiAntonio, from the Air Combat Command for both the support and latitude provided to me in this endeavor. I hope this solution is helpful. Additional thanks go to Mr. Bill Lloyd for figuring out how to break down this problem into something manageable.

Mark A. Degenhardt

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METRIC DEVELOPMENT FOR CONTINUOUS PROCESS IMPROVEMENT

I. Introduction

Background

The use of Continuous Process Improvement (CPI) within organizations has become very popular in recent years. Since early pioneers invented machines that enabled and improved mass production, others have taken additional steps forward, such as creatively applying statistical methods to analyze processes and improve quality by reducing variation within processes. Today, some companies focus their CPI efforts on maximizing the quality of their products and services in order to improve customer satisfaction, while others use CPI as a mechanism for driving down costs. Still others aim to change the *culture* within their organization to one that rewards its members for sharing ideas that continually improve their internal business processes and policies.

In general, the purpose of CPI is to reduce costs, eliminate waste, increase efficiency, improve product quality, and maximize value to the customer. This is true for profit and non-profit organizations alike. For the Air Force, the *desired* effects of its CPI initiative, Air Force Smart Operations for the 21st Century (AFSO21), are to increase productivity of its personnel, increase critical asset availability, improve response time, maintain safe and reliable operations, and improve energy efficiency. Unfortunately, these effects have not yet been fully realized since the advent of AFSO21.

Problem Statement

AFSO21 is not currently being used as effectively as it could be across the Air Force. The Air Force website, Air Force Times, and other media sources tell about various success stories where processes are streamlined, hundreds of man-hours are cut, and thousands of American tax dollars are saved. These are obviously very good things, but the reader needs to question the effect that these scattered (and somewhat random) improvements have on the core mission. In other words, the question is: how can AFSO21 be used to get away from creating appealing headlines to truly making a difference for the Air Force?

Research Objective

The purpose of this research is to find a way to use CPI tools to go from simply saving money here or cutting man-hours there to solving the bigger issue of improving the Air Force's bottom line. For a business, the bottom line is profit. Therefore, to improve their bottom line is to increase profit. However, since the Air Force is a non-profit government entity, it can be argued that its bottom line is mission performance. In other words, the Air Force need to use CPI tools to "fly, fight and win" *better*.

Methodology

This research provides a methodology to identify specific target areas where continuous process improvement, i.e., AFSO21, should be applied to improve the bottom line of an organization. The first step in this process is to engage the decision maker to solicit the key performance indicators (KPIs) that best reflect the organization's mission.

The goal for this step is to make a list of the answers to the "why are we here" question. The second step is to use and/or develop appropriate metrics based on those KPIs to measure how well the organization is doing its mission today. The third step is to capture the trends of those KPIs over time to see if the organization is getting better or worse. The fourth and final step is to identify the largest performance capability gaps in order to determine where AFSO21 resources should be applied to get "the most bang for the buck". The result of this process should give the decision maker a clear snapshot of his/her organization's current ability to perform its mission. This, in turn, gives him/her the ability to improve the bottom line by targeting the weakest areas.

Scope

The methodology presented in this paper is applicable to any organization, which, by definition, is any entity that pursues collective goals, controls its own performance, and has a boundary separating it from its environment. This includes profit and non-profit organizations. The Air Force's Air Combat Command (ACC) will be examined as a case study for a specific application of the proposed methodology.

Paper Organization

This research presents a framework for applying CPI in order to improve the bottom line of an organization. In Chapter 2, the research begins by examining foundational concepts including various CPI methodologies, principles of metric development, basic tenets of regression analysis, and background information about ACC. In Chapter 3, the previous concepts are combined to establish a methodology for effectively employing CPI in an organization. Chapter 4 details the analysis performed and results achieved through application of the methodology to ACC. Finally, recommendations for further study and future implementation are provided in Chapter 5.

II. Literature Review

Introduction

The purpose of this literature review is to provide a foundation for the discussion about metric development for Continuous Process Improvement (CPI). It briefly introduces some common CPI methodologies, culminating with a description of AFSO21, which is the CPI methodology used by the Air Force. It also describes the key tenets of metric development and provides a description of the Air Combat Command (ACC) organization which will be used as the case study for the methodology in this thesis.

Continuous Process Improvement (CPI)

CPI Defined

Continuous Process Improvement (CPI) is problem solving. It refers to the integrated system of improvement that organizations use to analyze and improve their internal processes on a recurring basis by focusing on doing the right things, right (Liker, 2004). This concept stems from the Japanese term *kaizen*, which is a philosophy that emphasizes continuous improvement throughout all aspects of life; *kai* means "change" and *zen* means "good". As a way of thinking, CPI is relevant to any process, regardless of complexity or relative importance (Womack, 2003).

The Purpose of CPI

The goal of CPI is inherent in its name; to continuously improve products and services. Knowledge about what the customer wants is essential to achieving this goal because the customer determines what is of value (Womack, 2003). In the private sector, the goal of CPI is typically to reduce costs related to internal processes and people in order to increase profits and provide higher quality products to customers. In the military, the goal is to achieve lower cost, shorter lead times, and higher quality in order to deliver better products more quickly to the warfighter (AF Journal of Logistics, 2008).

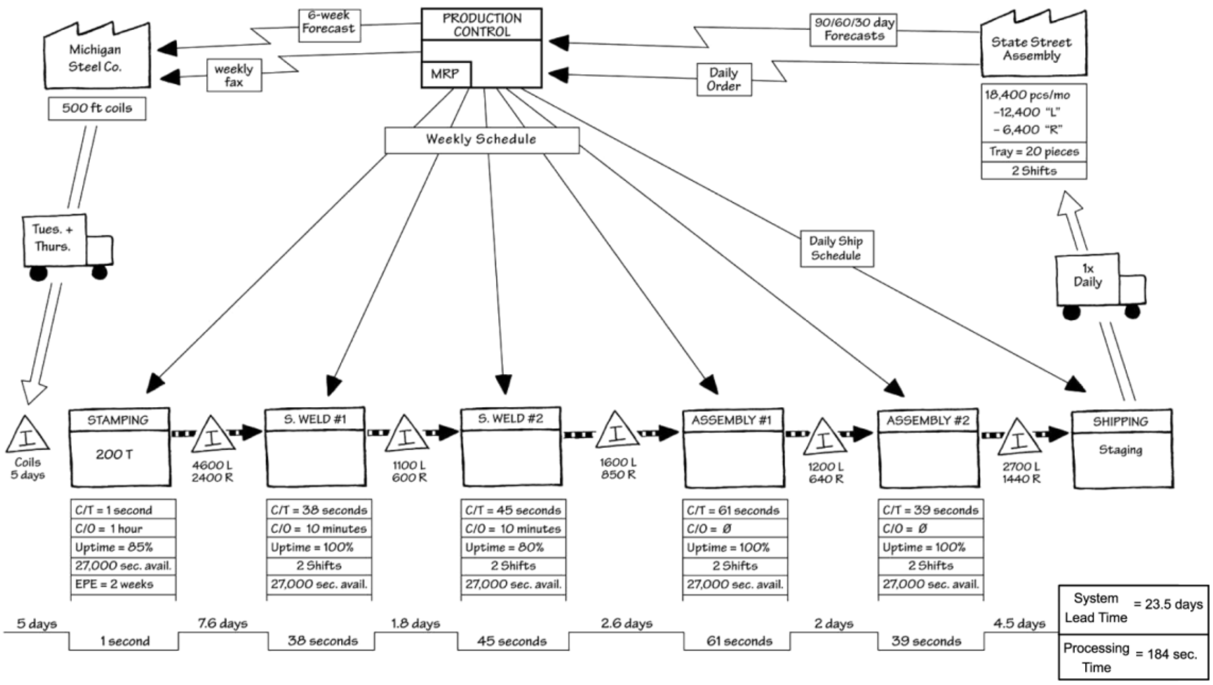
CPI Methodologies

Some of the CPI programs that are being used throughout corporate America include Lean, Six Sigma, Quality, Business Process Reengineering (BPR), and Theory of Constraints (TOC). Within the DoD, CPI programs have service-specific titles, such as the Navy's AIRSpeed, the Air Force's Smart Operations for the 21st Century (AFSO21), and the Army's Lean Six Sigma (LSS) program.

Lean

The fundamental premise of "lean" is the elimination of *muda*, or waste, in the workplace. Waste can be defined as "any activity that consumes resources but creates no value" (Womack, 2003). According to the best-selling book *The Toyota Way*, there are eight types of waste in the workplace: overproduction, waiting, unnecessary transport and conveyance, over processing (or incorrect processing), excess inventory, unnecessary movement, defects, and unused employee creativity (Liker, 2004). The purpose of being lean is to be able to identify and remove these types of waste to "do more and more with less and less – less human effort, less equipment, less time, and less space – while coming closer and closer to providing customers with exactly what they want" (Womack, 2003). Lean production is based largely on the Toyota Production System, Toyota's unique approach to manufacturing that allows them to use “fewer man-hours, less inventory (to produce) the highest quality cars with the fewest defects of any competing manufacturer” (Liker, 2004). Toyota pioneered this system after World War II during a time when American companies Ford and GM were using mass production and large equipment to produce as many parts as possible as cheaply as possible. Toyota, however, had a much smaller customer base, and had to produce a variety of vehicles in small quantities using the same assembly line. They realized that keeping lead times short and focusing on flexible production lines actually resulted in higher quality, better productivity, and better utilization of equipment and space (Liker, 2004). They were, in effect, doing more with less.

The fundamental tenets of lean production are value, the value stream, flow, pull, and perfection. Value is defined by the customer as the good or service that is being produced. The value stream refers to the series of sequential steps that the value takes through a process to reach its finished state when it is ready to be given to the customer. Figure 1 shows a value stream map for a company’s steel assembly fabrication process. In this example, the value is an individual part made out of steel provided by “Michigan Steel Co” (the supplier) for distribution to “State Street Assembly” (the customer). Flow refers to the ability of a value to move continuously from step to step in its production process without interruption or wasted motion; it is the contrary method to a batch-and-queue process. Pull, in its simplest terms, means that an item should not be produced until it is requested by its customer. This is in contrast to a “push” system, which attempts to predict customer demand and cover that demand with inventory. Pull systems provide the right amount at the right time; no more, no less, not early, not late. Finally, perfection is just that – repeating the leaning process until there is complete elimination of *muda* (Womack, 2003). Incorporating these tenets into a single effort with a focus on eliminating wasted time and resources at each step results in a fast, flexible process that gives customers what they want when they want it, at the highest quality and affordable cost (Liker, 2004).



Note: C/T = cycle time; C/O = change-over time; EPE = every part every ____
Source: Womack (2003)

Figure 1. Example of a Value Stream Map (Womack, 2003)

Six Sigma

While Lean focuses on making a process more *efficient*, Six Sigma is a methodology used to improve product *quality*. Six Sigma is defined as a comprehensive and flexible system for achieving, sustaining and maximizing business success. Six Sigma is uniquely driven by close understanding of customer needs, disciplined use of facts, data, and statistical analysis, and diligent attention to managing, improving, and reinventing business processes (Pande, 2000). Six Sigma was embraced by the Motorola Corporation as a method of improving customer satisfaction by increasing product quality. “Sigma (σ)” is a term in statistics that refers to the amount of variation of data points from the mean in a data set. Within the context of a normal distribution, this means that 99.99998% of all data points are within six standard deviations (six sigma) from the mean (see Figure 2). In business terms, this can be quantified as operating with only 3.4 defects per million opportunities, where a “defect” is defined as any instance or event in which the product or process fails to meet a customer requirement. A company that is able to fine-tune its products and processes to this level will be near-perfection in meeting customer requirements (Pande, 2000).

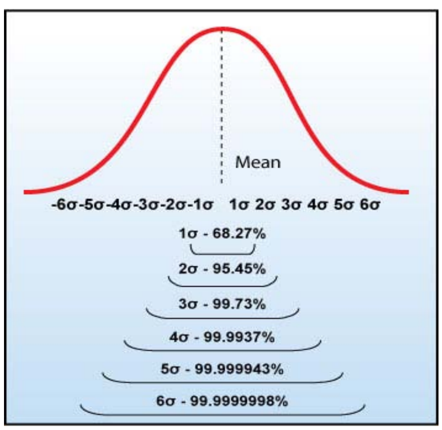


Figure 2. "Six Sigma" deviations from the mean (Pande, 2000)

The Six Sigma model used to guide process improvement is called the “DMAIC” model, which is a five-step process used to Define, Measure, Analyze, Improve, and

Control product and process defects (Pande, 2000). Figure 3 depicts the “DMAIC” model below:

Figure 3. "DMAIC" model (Pande, 2000)

The DMAIC model consists of the following five steps:

- <u>Define</u> the process by identifying the customers, identifying what is important to the customers, and identifying existing output conditions.
- <u>Measure</u> the process by using metrics to collect data.
- <u>Analyze</u> the data results to identify the most important causes of the problems.
- <u>Improve</u> the process by developing and implementing solutions.
- <u>Control</u> the process means that once the process is within performance standards, it is monitored.

Lean Six Sigma

Lean Six Sigma, as the name implies, combines Lean and Six Sigma to achieve greater process improvement gains. The purpose of Lean is to minimize waste (increase efficiency) and that of Six Sigma is to reduce variation (increase effectiveness). The result of the combination is the customer will receive a defect-free product faster. In general, Lean techniques will result in more immediate gains. Improvements from Six

Sigma application will take longer. Using the methods together will maximize productivity and ensure customers are getting what they need, when they need it (George, 2002).

Lean and Six Sigma principles can be applied to logistics and supply chain operations. In their book *Lean Six Sigma Logistics: Strategic Development to Operational Success*, Thomas Goldsby and Robert Martichenko developed a useful tool they refer to as the "bridge" model (see Figure 4).

Figure 4. Lean Six Sigma Logistics "Bridge" Model (Goldsby, 2005)

The guiding principles of this model for solving logistics challenges are logistics flow, logistics capability, and logistics discipline, which form a "bridge" between a company and its customers. Logistics flow refers to the movement of assets, information, and financial data across the bridge. Logistics capability encompasses predictability, stability, and visibility of the company's processes. Logistics discipline refers to collaboration, systems optimization, and waste elimination (Goldsby, 2005).

Business Process Reengineering

Reengineering is defined as the fundamental rethink and radical redesign of business processes to generate dramatic improvements in critical performance measures -

- such as cost, quality, service and speed. The basic idea is to start with a blank sheet of paper, forget about current processes and traditions, take what is known about customers and their preferences, and develop completely new "optimized" business processes. The goal is to produce simplified business processes, empowered personnel, and a shift of emphasis from individual to team achievements (Hammer, 2003).

Theory of Constraints

The Theory of Constraints (TOC), developed by Dr. Eliyahu M. Goldratt, is based on the idea that quality and productivity will increase if various constraints are removed. The philosophy emphasizes that a single constraint or bottleneck exists in any process and controls the output from the entire process. A constraint is anything that hinders an organization in reaching its goals. There are two types of constraints: physical and non-physical. Some examples of physical constraints are warehouse space, machine capacity, or number of delivery vehicles. Some examples of non-physical constraints are employee attitudes, customer demand, or company procedures. Each type of constraint must be identified, categorized, and treated accordingly in order to manage performance.

TOC can be applied to manufacturing processes, such as inefficient factory layouts, wrong quantity or type of inventory, or schedule problems, and to management processes, such as outdated policies or procedures (Goldratt, 1992). TOC uses a six-step process to enable ongoing improvement:

1. Identify the system's constraints
2. Decide how to exploit the system's constraints
3. Subordinate everything else to the decision in step 2
4. Elevate the system's constraints
5. If the system's constraints were changed, return to step 1
6. Change the system if required

TOC is not a substitute for other CPI tools; it should be used in conjunction with other CPI tools to reap maximum benefits. Although each of the CPI methodologies has different tool sets and different goals, there is a common thread — all involve reducing or removing barriers to customer service. Six Sigma reduces variation, Lean reduces waste, and TOC reduces constraints. Table 1 below, created by the Defense Acquisition University (DAU) for CPI familiarization training, depicts a comparison of each of these tools.

Table 1. Comparison of Six Sigma, Lean, and Theory of Constraints (DAU, 2006)

Program	Six Sigma	Lean Thinking	Theory of Constraints
Theory	Reduce Variation	Remove Waste	Manage Constraints
Application Guidelines	1. Define 2. Measure 3. Analyze 4. Improve 5 Control	1. Identify Value 2. Identify Value Stream 3. Flow 4. Pull 5. Perfection	1. Identify Constraint 2. Exploit Constraint 3. Subordinate Process 4. Elevate Constraint 5. Repeat Cycle
Focus	Problem Focused	Flow Focused	Systems Constraints
Assumptions	A problem exists. Figures and numbers are valued. System output improves if variation in all processes is reduced.	Waste removal will improve business performance. Many small improvements are better than systems analysis.	Emphasis on speed and volume. Uses existing systems. Process interdependence.
Primary Effect	Uniform process output	Reduced flow time	Fast throughput
Secondary Effects	Less variation. Uniform output. Less inventory. Fluctuation - performance measures for managers. Improved quality.	Less waste. Fast throughput. Flow - performance measure for managers. Improved quality.	Less inventory/waste. Throughput cost accounting. Throughput - performance measurement system. Improved quality.

Business Case Analysis

In the context of this paper, a business case is a presentation that captures the reasoning for initiating a process improvement project. It is not a CPI methodology itself. A business case captures various characteristics of a proposed process improvement project, such as the background of the project, expected benefits, expected costs, the alternatives considered, the expected risks associated with each alternative, and the implementation timeline. A business case analysis is "a systematic examination of alternatives resulting in a recommendation based on the 'corporate' good" (AFSO 21 Playbook, 2007). The main goal is to help management make an informed decision whether a proposed process improvement effort should be undertaken.

Change Management

Similarly, change management is not a CPI methodology in itself, but it is a necessary function in order to successfully employ any major process improvement effort. Organizational change management refers to the processes and tools used for managing the human side of corporate change. According to Brien Palmer in his book *Making Change Work: Practical Tools for Overcoming Human Resistance*, changes that fail usually do not fail because of technical reasons – something inherently flawed about the change itself (2003). They usually fail because of human reasons; i.e., the promoters of the change did not attend to the healthy, real, and predictable reactions of normal people to disturbances in their routines. Overcoming these human barriers requires a special kind of leader, or a change agent, who has the clout, the conviction, and the charisma to make things happen (Womack, 2003). Effective change management is a critical element of any process improvement activity.

The Roll-up: Air Force Smart Operations for the 21st Century

AFSO21 is an improvement model customized to the unique environment of the United States Air Force which leverages improvement methods from various sources, such as Lean, Six Sigma, Theory of Constraints and Business Process Reengineering with the ultimate objective of improving combat capability (AFSO21 Playbook, 2007). AFSO21 uses portions of these methods to increase operational support, kill non-value-added work, use "clean sheet" thinking, improve how we operate, and identify gaps within Air Force operations to maximize value and eliminate waste. The desired effects of these Smart Operations are to increase productivity of Air Force personnel, increase critical asset availability, improve response time and decision making agility, sustain safe and reliable operations, and improve energy efficiency.

According to the Director of ACC/A9, AFSO21 is comprised of four components: CPI, performance measurement, the 8-step problem solving process, and Strategic Alignment and Deployment (SA&D). The first component, CPI, has already been discussed. The focus of the second component, performance measurement, is to ensure that the right types of performance (i.e., results vice activity) are being measured the right way (i.e., using effects-based data to track specific progress from a known starting point to a new end-state). This is referred to as a "baseline-to-target" approach. The third component consists of the following eight-step problem-solving approach:

1. Clarify The Problem
2. Break Down The Problem/Identify Performance Gaps
3. Set Improvement Target
4. Determine Root Causes
5. Develop Countermeasures

6. See Countermeasures Through
7. Confirm Results and Process
8. Standardize Successful Processes

The first step is critical because the team must understand which problem needs to be solved in order to be in the best position to solve it. The second step involves gathering objective data and reviewing appropriate metrics in order to determine the root cause of the problem. The third step entails setting a specific, measurable, attainable goal for the desired effect of the process improvement effort. The purpose of the fourth step is to identify and attack the source of the problem, as opposed to performing "quick fixes" on the symptoms of the problem. This will ensure the problem doesn't occur again in the future. The purpose of step five is to come up with a quality solution that is practical, effective, and accepted by the stakeholders affected by its implementation. The purpose of step six is to implement the plan developed in the previous steps. Step seven entails a comparison of the metrics of the new process with the old process to determine if the improvement effort was a success. The purpose of step eight is to ensure the implementation of the new process is standardized and that the results of the new process stick.

The final aspect of AFSO21, Strategic Alignment & Deployment (SA&D), refers to the DoD methodology for aligning CPI efforts with strategic policy. SA&D is the process of cascading or communicating policy from top to middle management and throughout the rest of the organization using a give-and-take process called "catchball". According to DoD Instruction 5010.43, *Implementation of DoD-wide CPI/Lean Six Sigma*, "DoD components must identify organizational mission, priorities, and goals from top to bottom within an enterprise" and "leaders shall apply accepted CPI concepts through a disciplined deployment approach that is focused on the alignment of goals and priorities throughout the organization". The purposes of SA&D are to execute strategy, maintain focus on objectives, and measure performance on meeting those objectives along the way (DoDI 5010.43, 2009). Figure 5 shows the strategic policy deployment model for CPI in the DoD.

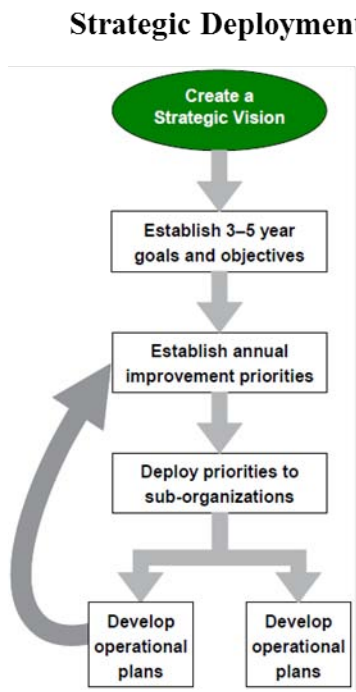


Figure 5. DoD Strategic Deployment Model (DoD CPI Guidebook, 2008)

The first step of SA&D is to review the organization's mission, priorities and goals. The second step is to deploy those objectives down to the lowest level in the chain of command. The third step is to establish metrics for achieving those objectives at each level in the chain in order to quantify how well the organization is meeting its objectives at all levels. The fourth step is to establish a performance baseline against those objectives using the appropriate metrics. The fifth step is to examine that baseline and identify improvement opportunities for closing performance gaps. The sixth step is to do a CPI event on the appropriate improvement target area. The final step is to collect and review data after the improvement effort to determine its effects on the organization's mission (2009). This paper proposes a methodology for implementing steps three through five of SA&D at the enterprise level of an organization.

What AFSO21 Is Not

AFSO21 is not a substitute for commanders' responsibilities at all levels. It is not a substitute for improved Air Force corporate management processes. And it is not another fad for process improvement like Total Quality Management (TQM) that is here today and gone tomorrow (AFSO21 Playbook, 2007). With the right type of leadership and buy-in from individuals at the middle management and working levels, AFSO21 is a systematic methodology that has the potential to help organizational units streamline internal processes, better utilize their workforce, and produce higher quality products more efficiently.

Metric Development

Measurement Basics

A metric is defined as a standard of measurement (Miriam-Webster), where measurement is the objective representation of objects, processes, and phenomenon (Finkelstein, 1984). Measurement captures information about systems through their attributes, which can be either directly or indirectly observable (Cropley, 1998).

All measurement is done within a context (Morse, 2003), which is shaped by a purpose, existing knowledge, capabilities, and resources (Brakel, 1984). Within this context, measurement begins by identifying the system of interest and the attributes to be used in defining the system. In the context of business, a metric is a measure used to evaluate an organization's progress toward its goals (Kirkwood, 1997). Attribute selection is important because the validity of a system measurement is influenced by the number of attributes used in the measurement. If the wrong system attributes are chosen, the perceived state of a system may be different from the actual state, so this is a key consideration of any framework for effectiveness measurement (Potter, 2000). In addition to the type of attributes chosen, the number of attributes selected must be considered. Fewer attributes will simplify the measurement process, but too few can result in poor and/or misleading insights about the system (Sink, 1985). Once the appropriate set of attributes is identified, data collection on the system can take place.

Types of Scales

The most common scale types are the Nominal, Ordinal, Interval, Ratio, and Absolute scales (Sarle, 1995). A nominal scale only contains equivalence meaning. The ordinal type has both equivalence and rank order meaning. Interval measures have these two meanings as well, but also have meaning in the intervals between the values. Ratio measurement further adds meaning in the ratios of values. Finally, absolute scales measure ratios without units (Ford, 1993). Figure 6 shows the relationships between these scales.

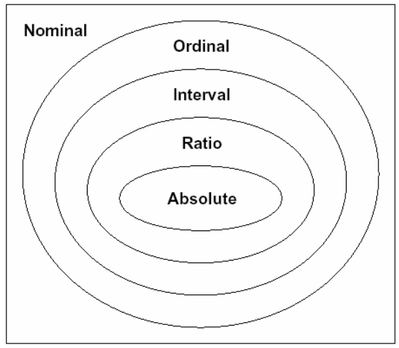


Figure 6. Scale Hierarchy of Commonly Used Measures (Ford, 1993)

Measurement scales can be further categorized as either natural or constructed, and as direct or proxy. A natural scale is one that is accepted, understood, and used by everyone. For example, profit in dollars is a natural scale that is used for many business decisions. A constructed scale is one that must be created for a particular type of problem because there is none that exists naturally to measure how well an objective that is specific to that problem is achieved. For example, a teacher uses a constructed scale of letter grades to measure students' comprehension of concepts they have been taught. In this case, the letter grades A, B, C, D, and F represent scores which are ≥ 90, ≥ 80, ≥ 70, ≥ 60, and <60, respectively. A direct scale directly measures the degree of attainment of an objective, whereas a proxy scale measures an associated objective, i.e. one that acts as a substitute (Kirkwood, 1997). A proxy measure is essentially a model or approximation of the system attribute of interest (Potter, 2000). For example, the number of dollars is a direct scale used to measure "profit", whereas gross national product is a proxy (substitute) scale for measuring "the economic well-being of the country". These two distinctions actually represent the range of scale types that can be used, from the previous example of profit, which uses a natural direct scale to measure the amount of money earned, to class grades, by which professors use a constructed proxy scale to measure a person's intelligence (Kirkwood, 1997). Other examples can be found in Table 2.

Table 2. Measure Types (Kirkwood, 1997)

	Natural	**Constructed**
Direct	Commonly understood measures directly linked to strategic objective Example: Profit	Measures directly linked to the strategic objective but developed for a specific purpose Example: Gymnastics scoring
Proxy	In general use measures focused on an objective correlated with the strategic objective Example: GNP (economic well being)	Measures developed for a specific purpose focused on an objective correlated to the strategic objective Example: Student grades (intelligence)

MOEs and MOPs

Measurement is fundamental to understanding, controlling, and forecasting (Wilbur, 1995). Measures of effectiveness (MOEs) and measures of performance (MOPs) provide different insights about a system. A MOE concerns how well a system tracks against its purpose (Sproles, 1997). However, a MOP describes how well a system uses resources (Sink, 1985). In other words, a MOE determines if the right things are being done, and a MOP determines if things are being done right (Sproles, 1997). The key distinction between the two is that a MOP measures *activity*, but it does not indicate a system's progress toward its purpose.

Key Performance Indicators (KPIs)

Many terms are often used to describe the result of an observation, such as measurement, indicator, or metric. In the context of business, key performance indicators (KPIs) are the few vital statistics that indicate the health of an organization. They are the quantifiable measures of effectiveness, efficiency, and quality which reflect the performance of an organization in achieving predefined strategic goals and objectives. KPIs measure effectiveness by determining if the organization has done what they said they would do, efficiency by comparing how many resources were actually used to how many were planned to be used, and quality by gauging if the planned efforts were done well (Sink/Tuttle, 1989).

There are two types of indicators: lagging and leading. Lagging indicators, such as most financial metrics, measure the output of past activity, i.e., they are collected and reported after the fact. Lagging indicators are useful for tracking trends, but by the time the trend is noticed, there may already be problems. Leading (outcome-based) indicators measure key drivers of business value and can be used as future performance drivers for an organization (Kaplan/Norton, 1996). KPIs are the critical drivers for mission success. KPIs are metrics, but not all metrics are KPIs.

Traps of Metrics

There are literally thousands of metrics to choose from; the difficulty lies in identifying the right ones. It is easy to use metrics that do not measure the aspects that pertain to an organization's specific problem. Another issue is "paralysis by analysis". When data is not tied to the organization's KPIs, employees end up spending a lot of time collecting and analyzing data that doesn't impact the bottom line (Kaplan/Norton, 1996). A specific instance of this occurs when an organization uses activity (input) metrics versus results-focused (output) metrics. Basically, they end up reporting status on the *work* they're doing to meet improvement goals, instead of reporting on the organization's *actual progress* toward meeting its goals (Potter, 2000). Creating metrics that have the following characteristics will help organizations avoid running into these and other traps.

Characteristics of Effective Metrics

The key to successful measurement is ensuring the right measures are being used to gauge the system's purpose (Brown, 1996). Effective metrics share some of the following characteristics: strategically-linked, timely, objective, complete, obtainable, and valid.

- Strategically-linked – Effectiveness measures should be traceable to the organization's strategic purpose (Kaplan, 1991). Metrics should be specific and targeted to the organization's KPIs to ensure they only measure the outcomes that have value to the customer (Kaplan/Norton, 1996).

- Timely – Measures should be collected and processed in a timeframe that is needed to be relevant within the context (Kaplan, 1991).

- Objective – Measures should be easy to understand. It should be clear when you chart your performance over time which direction is "good" and which direction is "bad", so that you know when to take action (Finkelstein, 2003).

- Complete – Measures should address all KPIs in enough detail to accurately depict the status of the key mission areas of the organization (Kaplan, 1991). The number of measures should be limited in order to avoid information overload.

- Obtainable – Measures should be readily and easily obtainable from available sources (Keeney, 1992).
-
- Valid – Measures should actually measure what is intended to be measured in order to be meaningful (Carton, 2006).

Displaying Metrics

Finally, an important, but often underemphasized aspect of system measurement is communicating the information. The goal for an information display should be to present the maximum amount of information possible while ensuring unambiguous understanding of the insights it presents (Tufte, 1997). An increasingly popular method of displaying information is through the use of a metrics dashboard (Eckerson, 2006).

Unfortunately, there is no comprehensive method for developing a complete set of measures. However, achieving completeness typically requires both critical and creative thinking in an iterative process involving negotiation and compromise among those interested in and knowledgeable about the system (Sproles, 2002).

Linear Regression

According to Kutner, Nachtsheim, Neter, and Li, “regression analysis is a statistical methodology that utilizes the relation between two or more quantitative variables so that a response or outcome variable can be predicted from the other, or others” (Kutner, et al, 2005).

Regression is used in a variety of disciplines, from business to behavioral sciences, for three major purposes: description, control, and prediction. When considering the concept of a relation between variables, Kutner highlights the importance of distinguishing between a *functional relation* and a *statistical relation*. A functional relation between two variables is expressed by a mathematical formula. For example, if X_1, X_2, X_3, and X_4 denote the *independent variables* and Y the *dependent variable*, a functional relation is of the form:

$$Y = f\,(X_1,X_2,X_3,X_4)$$

Given a particular value of each X, the function *f* indicates the corresponding value of Y. Figure 7 shows an example of a functional relation between the predictor variable “Units Sold” and the single response variable “Dollar Sales”.

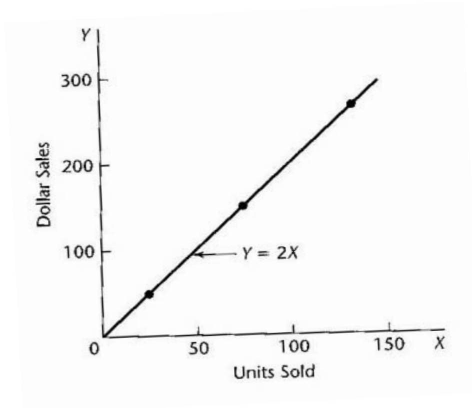


Figure 7. Example of Functional Relation (Kutner, 2005)

A statistical relation, on the other hand, is not perfect like a functional relation, because observations for a statistical relation generally do not fall directly on the curve of relationship. Figure 8 below shows an example of a statistical relation between the predictor variable "Midyear Evaluation" and the response variable "Year-End Evaluation".

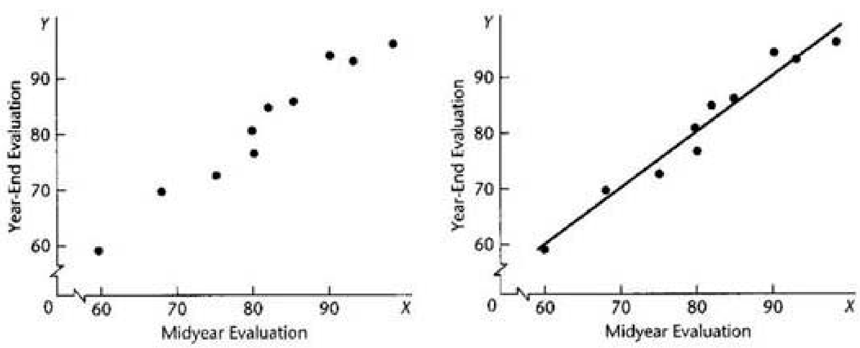


Figure 8. Example of Statistical Relation (Kutner, 2005)

The *coefficient of determination,* R^2, is a measure that may be interpreted as the proportionate reduction of total variation associated with the use of the predictor variable X (where $0 \leq R^2 \leq 1$). Thus, the larger R^2 is, the more the total variation of Y is reduced by introducing the predictor variable X (Kutner, 2005). Basically, R^2 indicates how well a regression model describes the relation between the observed values of X and Y.

The *correlation coefficient, r,* represents the measure of linear association between Y and X when both Y and X are random. It can vary from 0 (which indicates no correlation) to ±1 (which indicated perfect correlation). When the correlation coefficient is greater than 0, the two variables are said to be positively correlated; i.e., when one is large, the other is also large. When it is less than 0, they are said to be negatively correlated; i.e., when one is large, the other is small (Makridakis, 1998).

Case Study: Air Combat Command (ACC)

ACC is the primary force provider of combat airpower to America's warfighting commands. ACC operates fighter, bomber, reconnaissance, battle-management, and electronic-combat aircraft to support global implementation of a national security strategy. ACC also provides command, control, communications and intelligence systems, and conducts global information operations. In addition, ACC "organizes, trains, equips and maintains combat-ready forces for rapid deployment and employment while ensuring strategic air defense forces are ready to meet the challenges of peacetime air sovereignty and wartime air defense" (www.my.af.mil).

The Commander of ACC (COMACC) has two roles: one is to organize, train, and equip the forces within ACC, and the other is to direct the actions of the Combat Air Force (CAF). The CAF is a collection of Air Force organizations, commands and forces tasked to generate specific precise effects from the air, space, and cyberspace. The CAF's mission is to "Fly, Fight, and Win -- integrating capabilities across air, space, and cyberspace to deliver precise coercive effects in defense of our Nation and its global interests” (CAF Strategic Plan 2010).

The ACC/A9 AFSO21 office manages the CPI program for Headquarters ACC. According to the Director of ACC/A9, “Excellence in all we do directs us to develop a sustained passion for the continuous improvement and innovation that will propel the Air Force into a long-term, upward spiral of accomplishment and performance.”

III. Methodology

This chapter presents a methodology for developing metrics to identify how and where to use continuous process improvement (CPI) in an organization. Each step will be described for the general case, followed by an example of a specific application to the ACC case study.

In order for an organization to implement CPI methods effectively, it must have the right objective from the outset. Contrary to popular belief, the ultimate goal of CPI is not to simply save money or reduce man-hours (though these are certainly positive side effects). No, for an organization to achieve success it must go much deeper than these "symptoms" and examine its sole purpose for existence: it must identify its bottom line. In addition to identifying the right objective at the beginning, CPI must be aligned with the strategic priorities of the organization's leadership (Sink/Tuttle, 1989). In chapter 2, how this is done in the DoD via the SA&D process is discussed.

Arguably, the sole purpose for existence for any company is to make a profit. Consider the previous examples of saving money and reducing man-hours. The *reason* for saving money (i.e., reducing operating costs) is to increase profit. Likewise, the *reason* for cutting man-hours (i.e., reducing labor costs), is to increase profit. Therefore, for a CPI event to have the most success with lasting results for a company, the target for improvement must be the bottom line, which is to increase profit.

The military, however, does not work for profit, so how do we define our bottom line? According to Sink and Tuttle, improving *performance* is the bottom line (Sink/Tuttle, 1989). The current mission of the US Air Force is "to fly, fight and win…

in Air, Space, and Cyberspace" (Air Force Fact Sheet, 2010). Our primary shareholders, the American public, expect us to perform our mission *well* in order to protect our nation. To that end, the Air Force's bottom line is our *warfighting capability*. It's just not about "doing more with less". It's about doing what we do better.

As noted previously, ACC's mission is to provide forces of combat airpower to America's warfighting commands. Therefore, ACC's bottom line is *readiness* to provide warfighting capability. According to DoD Directive 7730.65, *readiness* is defined as "a measure of the Department of Defense's ability to provide the capabilities needed to execute the missions specified in the National Military Strategy" (2007). The Combat Air Force (CAF) Strategic Plan states that winning the current fight and deterring/winning the future fight requires "a credible, *ready* force", and the decision maker for ACC, the COMACC will "place increased emphasis on *readiness*" (2010, emphasis added). Therefore, the COMACC values *readiness* as the critical indicator for his organization's ability to perform its mission.

Now that the decision maker's values have been determined, the next step is to choose appropriate KPIs that can be used to signify how well the organization is meeting its bottom line. For the ACC case study, the primary KPI, readiness, can be measured using ratings from the Status of Resources and Training System (SORTS), Operational Readiness Inspection (ORI) reports, the Defense Readiness Reporting System (DRRS), and the AEF (Air Expeditionary Force) Unit Type Code (UTC) Status Reporting Tool (ART). AFI 10-201 *SORTS* states that,

> "SORTS is the single automated reporting system within
> the Department of Defense (DoD) functioning as the

> central registry of all operational units of the US Armed Forces and certain foreign organizations. SORTS has a threefold purpose: it provides data critical to crisis planning, provides for the deliberate or peacetime planning process, and is used by the Chief of Staff United States Air Force (CSAF) and subordinate commanders in assessing their effectiveness in meeting Title 10, "United States Code," responsibilities to organize, train, and equip forces for combatant commands. The Air Force uses SORTS status information in assessing readiness, analyzing readiness trends, and supporting readiness decisions. SORTS provides broad bands of information on selected unit status indicators which include the commander's assessment of the unit's ability to execute the mission set for which it is organized or designed (AFI 10-201, 2006, emphasis added)".

In addition to SORTS reports, AFPD 10-2 *AF Readiness* dictates that "the Air Force will continually assess readiness based on criteria established by the Secretary of Defense, CJCS, Secretary of the Air Force and the Chief of Staff of the Air Force. Training, exercise evaluation and inspection assessments are critical and will be used for readiness assessments" (AFPD 10-2, 2006). These assessments are called ORIs, which are described in AFI 90-201 *Inspector General Activities* below:

> "ORIs evaluate and measure the ability of units to perform their wartime, contingency, or force sustainment missions. Phase I evaluates the unit's transition from peacetime readiness and the unit's ability to maintain and sustain essential home station missions during and after the deployment of forces and includes the major graded area (MGA) of Positioning the Force. Phase II evaluates the unit's ability to meet wartime/contingency taskings through the MGAs of Employing the Force, Sustaining the Force, and Ability to Survive and Operate (ATSO)".

AFI 10-244 *Reporting Status of AEFs* describes the AEF as "the Air Force's methodology for organizing, training, equipping, and sustaining rapidly responsive air and space forces to meet defense strategy requirements. Through the AEF, the Air Force supports defense strategy requirements using a combination of both permanently assigned and rotational (allocated) forces" (2008).

Readiness can also be measured using the DRRS, which is described in AFPD 10-2 *AF Readiness* as "an OSD net-centric, web-enabled initiative to manage and report the *readiness* of DOD forces to execute the National Military Strategy (NMS). All Air Force *readiness* related programs and processes will be aligned with DRRS initiatives" (2006, emphasis added). According to DoD Directive 7730.65 *DRRS*, this system is used to measures and report on the *readiness* of military forces and the supporting infrastructure to meet missions and goals assigned by the Secretary of Defense. DRRS is "a capabilities-based, adaptive, near real-time *readiness* reporting system for the Department of Defense" (2007, emphasis added). The DRRS User Guide says that DRRS "assesses a deployed unit's ability to perform its mission essential tasks while assigned to a Combatant Commander (COCOM). The Air Force identifies Unit Type Code (UTC) elements that can be deployed separately or as part of a capability package to support a designated operation" (2010).

In addition to DRRS, the AEF Reporting Tool (ART) is also used to assess deployment readiness, which is introduced in AFPD 10-2 *Readiness*:

> "the ART allows AEF allocated units the ability to report UTC level readiness data. It allows immediate updates and ready access to an aggregate UTC status for all levels of command with sufficient depth of information to make informed decisions on the employment of Air Force capabilities across the full range of military operations. Integration of DRRS and ART is critical to provide the required visibility of Air Force capabilities and resources while supporting the AEF construct."

ART measures the unit's ability to meet the Combatant Commander's (COCOM) requirements outlined in operational plans.

Once KPIs have been chosen, the next step is to solicit metrics and success criteria from the decision maker to determine how the organization is performing. Per AFI 10-201, SORTS documents and measures four categories that determine the unit's ability (readiness) to perform its mission based on the unit's full wartime requirement for which it was organized or designed:

1. Personnel – This refers to the number of personnel assigned, authorized, and available to perform the unit's mission based on Unit Manning Document or UTC requirements.
   This category is denoted by the letter "P" on SORTS reports.

2. Training – This refers to the required training for personnel assigned to the unit to perform the mission.
   This category is denoted by the letter "T" on SORTS reports.

3. Equipment/Supplies – This refers to the number and type of equipment required to perform the unit's mission.
   This category is denoted by the letter "S" on SORTS reports.

4. Equipment Condition – This refers to the condition of possessed equipment and supplies required to perform the unit's mission.
   This category is denoted by the letter "R" on SORTS reports.

AFI 10-201 states that "category-levels (C-levels) reflect the degree to which unit resources meet prescribed levels of personnel, equipment, and training". Each of the four categories (P, T, S, and R) is assigned a C-level on a scale of 1 to 6, where 1 and 4 represent the best and worst ratings, respectively, and C-levels of 5 and 6 are used to indicate that the unit is not required to report at the present time (C-levels of 5 and 6 are not used as ratings). C-levels are defined as follows:

C-1. The unit possesses the required resources and is trained to undertake the *full wartime mission(s)* for which it is organized or designed. The resource and training area status will neither limit flexibility and methods for mission accomplishment nor increase vulnerability of unit personnel and equipment. The unit does not require any compensation for any deficiencies.

C-2. The unit possesses the required resources and is trained to undertake *most of the wartime mission(s)* for which it is organized or designed. The resource and training area status may cause isolated decreases in flexibility in methods for mission accomplishment, but will not increase the unit's vulnerability under most envisioned operational scenarios. The unit would require little, if any, compensation for deficiencies.

C-3. The unit possesses the required resources and is trained to undertake *many, but not all, portions of the wartime mission(s)* for which it is organized or designed. The resource and training area status will result in significant decrease in flexibility for mission accomplishment and will increase vulnerability of the unit under many, but not all, envisioned operational scenarios. The unit would require significant compensation for deficiencies.

C-4. The unit *requires additional resources or training to undertake its wartime mission(s)*, but it may be directed to undertake portions of its wartime mission(s) with resources on hand.

C-5. The unit is *undergoing a Service-directed resource action* and is not prepared, at this time, to undertake the mission set for which it is organized or designed.

C-6. The unit is *not required to measure assets in a specified area*. C-6 (not a rating) may not be used as an Overall C-level.

AFI 10-201 instructs that "unit commanders assign the Overall C-level each time it is reported based on unit readiness. Normally, the lowest level of the four measured resource areas is reported as the Overall C-level provided it is a realistic indication of the unit's readiness (based on the C-level definitions)". In other words, the overall SORTS C-level for a particular unit is the maximum C-level of its sub-categories. For example, if the C-levels for a particular unit are P-3, T-2, S-2, and R-1, then the unit's overall readiness level is C-3. ACC is considered "Green" if 70% of its units are C-1 or C-2.

ORIs measure a wing's overall readiness "using the five-tier scale Outstanding, Excellent, Satisfactory, Marginal, and Unsatisfactory", as presented in AFI 90-201. ACC is considered "Green" if 100% of its wings are rated "Satisfactory" or higher.

The DRRS User Guide states that a unit that has been assigned mission essential tasks will use the following rating structure to classify its ability to "accomplish its task or mission to prescribed standards and conditions":

> Yes (Green): The organization can accomplish its mission essential task or mission to prescribed standards and conditions. The "Yes" assessment should reflect demonstrated performance in training or operations.
>
> Qualified Yes (Yellow): The organization can accomplish most or all of the task to standard under most conditions. The mission essential task assessment must clearly define the specific standard and conditions that cannot be met, as well as the shortfalls or issues impacting the unit's inability to accomplish the task.
>
> No (Red): The organization is unable to accomplish the mission essential task or mission to prescribed standards and conditions at this time.
>
> Not Assessed (Striped): The organization has not yet been assessed (DRRS User Guide, 2010).

When all of the mission essential tasks assigned to a unit have been assessed, that information is ready to be used towards assessing the overall mission capabilities. ACC is considered "Green" if 100% of deployed units report "Yes" or "Qualified Yes" in DRRS.

Per AFI 10-244 *Reporting Status of* AEFs, the overall assessment of a UTC is rated in ART using the following guidelines:

> Green = Go. All identified personnel, equipment and training for the AEF allocated UTC are available for deployment within 72 hours of notification or sooner if subject to more stringent criteria.
>
> Yellow = Caution. The UTC has a missing or deficient capability; but that missing or deficient capability does not prevent the UTC from being tasked and accomplishing its mission in a contingency and/or AEF rotation.
>
> Red = No Go. The UTC has a missing or deficient capability that prevents the UTC from being tasked and accomplishing its mission in a contingency and/or AEF rotation.

ACC is considered "Green" if 100% of UTCs are Green or Yellow.

Once data has been identified for each KPI, the next step is to retrieve that data from all source databases and combine into a single local database. It will likely be necessary to create a new database and adjust the format of the source data in order to make a common format for all data. For the ACC case study, ORI ratings are available on the ACC/IG website on the Air Force Portal. The search was narrowed to include all ORIs (Phase I, Phase II, and full inspections) for Active Duty units only from October 2008 through October 2010 (the time when this study was initiated). Then the data set was reduced by selecting only aviation wings. This resulted in 12 data points for ORIs during the analyzed timeframe. SORTS scores are available in monthly reports prepared by ACC/A3OR. ACC/A3 had collected this data monthly from the SORTS website on the Secret Internet Protocol Router Network (SIPRNet) and prepared their own PowerPoint briefings containing the data. (Historical data was not available through the SORTS website.) DRRS scores are available through the DRRS website on the SIPRNet. Note: DRRS scores were not used because the historical data was incomplete since all units were not yet required to report their scores during the analyzed timeframe. ART scores are available through the ART website on the SIPRNet. Note: ART scores were not used because historical data is not maintained on the ART website. A recommendation to maintain this data is included in Chapter 5.

Since each database has its own unique format, a single data table was created using Microsoft Excel to combine the data. Table 3 depicts this data table with notional data.

Table 3. Excel Data Table with Notional SORTS Scores

	A	D	E	F	G	H	I	J	K	L
1	Date	NAF #	Wing #	Unit #	Location	P	T	S	R	C-level (max)
2	20-Feb-09	5	1	3	Loc 24	3	1	1	1	3
3	9-Apr-09	5	1	3	Loc 24	3	1	1	1	3
4	17-Jun-09	5	1	3	Loc 24	3	1	1	1	3
5	20-Aug-09	5	1	3	Loc 24	4	1	1	1	4
6	15-Oct-09	5	1	3	Loc 24	4	1	1	1	4
7	21-Dec-09	5	1	3	Loc 24	4	1	1	1	4
8	20-Feb-09	5	1	4	Loc 24	1	3	1	1	3
9	15-Oct-09	5	1	5	Loc 24	3	1	1	1	3
10	17-Oct-08	5	1	6	Loc 24	2	1	4	1	4
11	18-Dec-08	5	1	6	Loc 24	4	1	4	1	4
12	20-Feb-09	5	1	6	Loc 24	4	1	4	1	4
13	9-Apr-09	5	1	6	Loc 24	3	1	4	1	4
14	17-Jun-09	5	1	6	Loc 24	3	1	4	1	4
15	20-Aug-09	5	1	6	Loc 24	3	1	4	1	4
16	15-Oct-09	5	1	6	Loc 24	2	1	4	1	4
17	21-Dec-09	5	1	6	Loc 24	2	1	4	1	4
18	20-Nov-08	5	1	8	Loc 24	4	1	1	1	4
19	22-Jan-09	5	1	8	Loc 24	4	1	1	1	4
20	20-Mar-09	5	1	8	Loc 24	3	1	1	1	3
21	16-Jul-09	5	1	8	Loc 24	4	1	1	1	4
22	9-Sep-09	5	1	8	Loc 24	3	1	1	1	3
23	17-Sep-10	5	1	8	Loc 24	3	1	1	4	4

Once all of the KPI scores have been collected, they should be examined for any interdependencies between them. The recommended tool for this situation is a linear regression model because it can reveal association between two or more variables, as well as predict values for a response variable y based on a set of explanatory variables x_1 through x_n, where n is the number of indicators chosen for a specific situation (Makridakis, 1998). For example, a company may be interested in predicting future sales for a particular product y based on three different indicators: past performance of the product (x_1), inflation rates (x_2), and time of year (x_3). For the ACC case study, the P, T, S, and R scores in SORTS (the explanatory variables) were tested for interaction between each other, as well as tested for their ability to predict the corresponding unit's ORI rating (the response variable). These results are outlined in Chapter 4 of this paper.

In order to create an accurate picture of the state of an organization's health, it is necessary to plot the KPI data for several periods leading up to the current period. The reason for this is to analyze trends to determine where the organization has come from, where it is today, and predict which way it's headed in the near future. For the ACC case study, SORTS scores for individual units should be plotted over the previous six months in order to sufficiently determine trends in the data. The current month's data for each organization will highlight the shortfalls between their required readiness level and its actual capability to perform its mission. This shortfall is also known as a capability gap.

Once the readiness capability gaps have been identified for each unit within the organization, each unit should be prioritized based on the largest capability gaps. This will identify those units that are most in need of continuous process improvement. At the working level, this simply means sorting the capability gaps in Excel from largest to smallest.

In order to make the previous work worthwhile and actionable, the results must be communicated clearly to the decision maker. The key here is to present the maximum amount of information possible while ensuring unambiguous understanding of the insights it presents (Tufte, 1997). This step entails presenting the plots for both the current period and the previous periods in order to portray the current state of the organization to the decision maker and highlight the units with the largest capability gaps.

IV. Analysis & Results

Assumptions

The data set examined is comprised of Active Duty Status of Resources and Training (SORTS)-reporting units that were part of Air Combat Command (ACC) between October 2008 and October 2010. This includes data for units that belong to the 8th Air Force, which were previously under ACC but are now under Air Force Global Strike Command (AFGSC). Data for Air National Guard (ANG) and Air Force Reserve Command (AFRC) units were not included in this study.

Limitations

SORTS scores are lagging indicators, which means that they measure the output of past activity. As noted in Chapter 2 of this paper, these scores are useful for tracking trends, but by the time a negative trend is noticed, there may already be problems.

Another limitation that surfaced during this study was the fact that ACC reports SORTS scores for aviation units and support units separately, on an alternating bi-monthly basis (i.e., scores for aviation units are reported during odd months, and scores for support units are reported during even months). And since SORTS data are not archived on the SORTS website, only half of the complete data set was available for this study.

Defense Readiness Reporting System (DRRS) and Air Expeditionary Force (AEF) Unit Type Code (UTC) Status Reporting Tool (ART) scores were introduced because of their usefulness to assess readiness. However, the Air Force deploys units, entities, etc. on the UTC system, so the deployed units measured by DRRS and ART are not the same as the home units measured by other systems, such as Operational Readiness Inspections (ORIs) and SORTS. Since this would be like "comparing apples to oranges", the DRRS and ART data were not included in this study. In addition, historical ART data is not currently being maintained, so it was also unavailable.

There were also limitations to performing regression analysis in this study. ORI scores are reported at the wing level only; they are not an aggregate of scores for the squadrons that comprise the wing. Similarly, SORTS scores are only assessed at the squadron level; they are not aggregated up to a wing-level score. Therefore, SORTS and ORI scores are not directly comparable, which severely limits the ability to draw conclusions about correlation and/or predictability between the different types of scores. Several methods were used in attempt to work around this issue, but to no avail.

Actual SORTS scores for individual units and specific results about trends and capability gaps are classified. These results will be replaced with notional data in order to communicate the methodology while preserving the sensitivity of the data. All other results are unclassified.

Analysis & Results

Once all of the SORTS and ORI data were collected and combined into one database, it was necessary to eliminate incomplete and erroneous SORTS observations from the data set. This included observations from units that no longer belong to ACC, observations that did not have a score in one or more of the P, T, S, or R categories, and observations where any of the categories were reported as C-6. Recall from Chapter 3 that C-6 is not a rating and may not be used as an overall C-level because the unit is not required to measure assets in a specified area (AFI 10-201, 2006). The remaining data set was comprised of over 1,300 usable observations, as depicted in Table 4 below:

Table 4. Observation Breakdown

	Total
# ORIs	12
Total Observations	1905
Non-ACC Observations	170
Bad Observations	393
Good ACC Observations	**1342**

Once the data set was purged of “bad” data, the first step was to use multivariate analysis to examine the SORTS and ORI scores for interdependencies. A correlation model was used to identify any possible causal relationship between the P, T, S, and R variables. A high correlation between any pair of these variables could identify the potential to impact one variable based on a change in another variable. For example, if P and T scores were correlated, this would imply that improving a unit’s personnel availability may also affect (and hopefully, improve) that unit’s training status. This hypothesis seems reasonable because people can only be trained if they are available. Correlation between the other variables could be used to make similar interpretations.

As it turned out, there was no apparent correlation between any of the SORTS variables. All correlation coefficients were below 0.25, indicating very low correlation. Table 5 below shows the correlation matrix for the SORTS scores.

Table 5. P-T-S-R Correlation Matrix

	P	T	S	R
P	1	-0.1751	-0.0654	-0.0282
T	-0.1751	1	0.1195	0.0623
S	-0.0654	0.1195	1	0.2360
R	-0.0282	0.0623	0.2360	1

The next effort was to examine the ability of SORTS scores to predict ORI ratings. In addition to the specific rating, the categories were broadened to assess the model's ability to predict whether the wing passed or failed each inspection. Specifically, a rating of "Outstanding", "Excellent", or "Satisfactory" is considered to be passing, while a rating of "Marginal" or "Unsatisfactory" is considered a failure.

However, since SORTS and ORI rankings are reported at different levels (squadron and wing, respectively), a workaround was used that involved applying a wing's ORI score onto all of the squadrons in that wing during the month of the ORI. For example, if the ORI rating for wing A (which is comprised of squadrons 1, 2, and 3) is "Satisfactory" in January 2010, then the rating for squadrons 1, 2, and 3 in January 2010 is "Satisfactory". The purpose for doing this was to have directly comparable data (i.e., "apples to apples"), as well as to generate more useable data points for the correlation and regression models. This enabled us to expand the 12 ORIs to 49 ORI/SORTS observations. The results for this method applied to the responses of ORI rating and pass/fail are shown in Table 6 below:

Table 6. Regression: Using SORTS Scores to Predict ORIs

Predictor	Obs	ORI Rating			ORI Pass/Fail	
		R^2	Source Effect	Correlation Coefficient	R^2	Source Effect
P Score	49	0.1485	> 0.1	0.1647	0.2659	0.0390
S Score			0.0333	0.2312		> 0.1
T Score			> 0.1	0.0502		> 0.1
R Score			0.0622	-0.0095		> 0.1

These results show that the R^2 values for both models were very low, which indicates that neither model was capable of accurately predicting ORI results. The low p-values indicate that the source effect of the S and R scores have comparatively more impact on the ORI rating than the P and T scores, but the low correlation coefficients indicate that there was very little dependence between any of the scores and the ORI rating. The P score seems to have more of an effect on whether the unit passes the ORI, but the low R^2 value invalidates any assumed predictive power. (Note: There are no correlation coefficients for the Pass/Fail model because the response variable was based on a character nominal scale.)

We also used various averages for the squadron SORTS scores in an attempt to reduce variability within the individual scores and capture values that incorporate the previous months leading up to the ORI. These variations include: taking the average across the P, T, S, R scores for each inspected wing, the average of each of the P, T, S, R scores for all squadrons within each inspected wing during the month of the ORI, and the average for all squadrons within each inspected wing over each month from one to six months prior to the inspection. All of these attempts yielded results similar to the first iteration presented above (see Table 7 below).

Table 7. Regression: Using SORTS Averages to Predict ORIs

		ORI Rating			ORI Pass/Fail	
Predictor	Obs	R^2	Source Effect	Correlation Coefficient	R^2	Source Effect
Sq Scores - Avg Across	49	< 0.1	0.0371	0.2337	< 0.1	> 0.1
Wg Avg - same month	48	< 0.1	> 0.1	0.0282	< 0.1	> 0.1
1-mo Avg	44	< 0.1	> 0.1	< .0001	< 0.1	> 0.1
2-mo Avg	44	< 0.1	> 0.1	0.0631	< 0.1	> 0.1
3-mo Avg	44	< 0.1	> 0.1	0.1194	< 0.1	> 0.1
4-mo Avg	40	< 0.1	> 0.1	0.1252	< 0.1	> 0.1
5-mo Avg	40	< 0.1	> 0.1	0.1417	< 0.1	> 0.1
6-mo Avg	40	< 0.1	> 0.1	0.1435	< 0.1	> 0.1

Unfortunately, the inherent problem with this approach was that the four predictor variables, which had considerable variance, were used to predict a response variable with no variance. This severely limited the predictive capability of the model. (A recommendation to report ORI rankings and SORTS scores at both the squadron and wing levels will be recorded in Chapter 5.)

Trends and Capability Gaps

After examining the dependencies within the data, the next step was to plot the data in order to analyze trends and identify capability gaps. In general, a capability gap can be measured by comparing the actual scores against a target value which is based on the decision maker's goals for the organization. For this study, the target SORTS score was 2 because ACC's goal is for units to be C-2 or better. What ACC would like to do is minimize the maximum P, T, S, R score for any unit, which is referred to as a *minimax problem.* (Winston, 2004) However, by simply reporting that minimax, much information is lost. Since the overall SORTS C-level is the maximum of the P, T, S, R scores, a unit's overall score is not necessarily representative of its actual health because not all sub-categories are reflected in the score. (A recommendation to change the method for determining overall SORTS C-levels is recorded in Chapter 5.) This issue was alleviated for this study by taking the average across the scores. This average doesn't have any mathematical meaning because it was taken across categories that measure different things, but it can be used as a metric that distinguishes between units that have the same overall (max) score.

Table 8 below illustrates this method. Suppose Squadron A has P, T, S, R scores of 4-1-1-1 and Squadron B has scores of 4-4-4-4. Both have the same overall SORTS score (C-4), but the reader can see that A is actually doing better than B. Taking the average of A's and B's scores (1.75 and 4.0, respectively) gives a much better feel for how well each unit is actually able to perform its mission. In addition, the average can be used to determine each unit's capability gap, which shows how close the unit's average score is from being C-2. In this example, Squadron A's gap is -0.25 and B's gap is 2.0. (The negative gap indicates that a unit is actually performing better than the target.)

Table 8. Determining a Unit's Overall Health

Sq	**P-T-S-R**	**C-level (Max)**	**Avg**	**Target**	**Capability Gap (Avg minus Target)**
A	4-1-1-1	4	1.75	2	-0.25
B	4-4-4-4	4	4	2	2

To apply continuous process improvement effectively, the decision maker should apply his resources using a systematic approach. He should prioritize the organizational units for improvement efforts according to the size of their capability gaps. A key aspect that enables this prioritization to work is the fact that the average scores for the lowest-level units can easily be aggregated to give the decision maker insight about his organization at all levels. In other words, the average score for any level in the hierarchy is the average of all lowest-level units under that level. For example, for ACC, the Major Command (MAJCOM), Numbered Air Force (NAF), and Wing averages are simply the averages of all squadrons contained within each of those organizations. Figure 9 shows this relationship hierarchically. In this case, the NAF 1 Average is the average of Wings 1-4, the NAF 2 Average is the average of Wings 5-7, and the NAF 3 Average is the average of Wings 8-11. Similarly, the MAJCOM Average is the average of Wings 1-11. All wing averages are the average of all squadrons contained in them (not depicted).

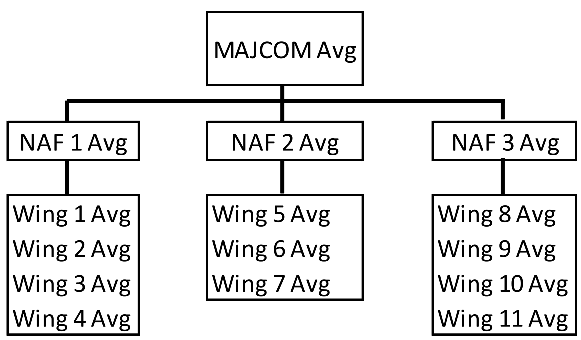


Figure 9. Aggregation of Squadron SORTS Scores

Since ACC's actual SORTS scores and the specific results of this study are classified, the following scenario will be used to communicate how this method of prioritization was used.

Suppose that on January 10, 2010, a NAF commander wanted to identify and improve the worst performing squadron in his organization. The NAF structure is presented below in Figure 10.

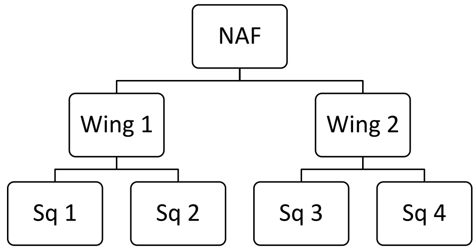


Figure 10. Notional NAF Structure

The first thing his team did was to plot the average squadron SORTS scores based on available data for Wings 1 and 2 from February 2009 through December 2009 (see Figures 11 and 12 below).

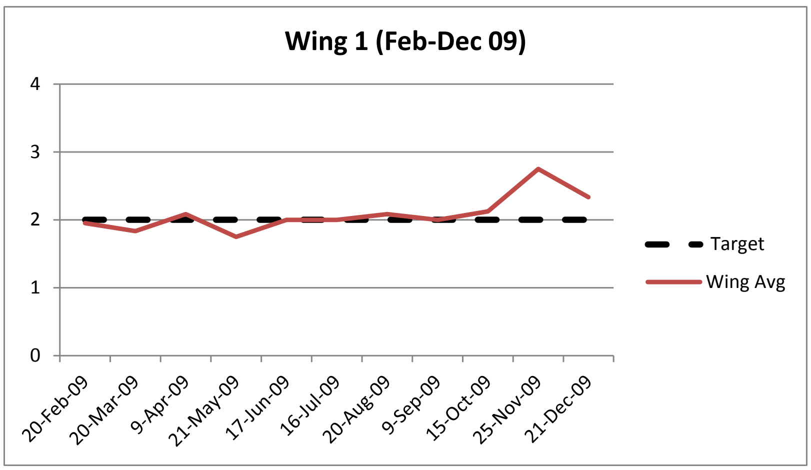


Figure 11. Plot of Notional SORTS Scores for Wing 1

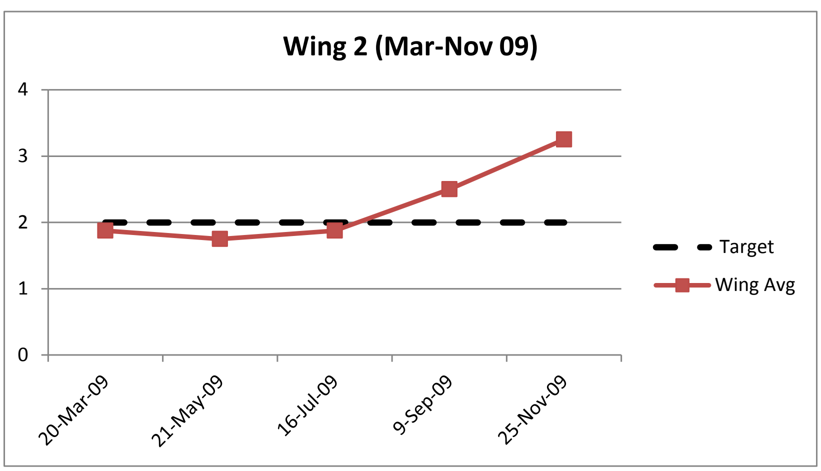


Figure 12. Plot of Notional SORTS Scores for Wing 2

The commander's team ascertained that Wing 1, with the exception of a late spike in November, was operating at a fairly steady level in line with the performance target. Wing 2, however, was getting considerably worse after performing nominally through September. Therefore, the team decided to dig deeper into Wing 2 by examining the performance of its sub-organizations, Squadrons 3 and 4. Figures 13 and 14 below are plots of the notional SORTS data for Squadrons 3 and 4, respectively.

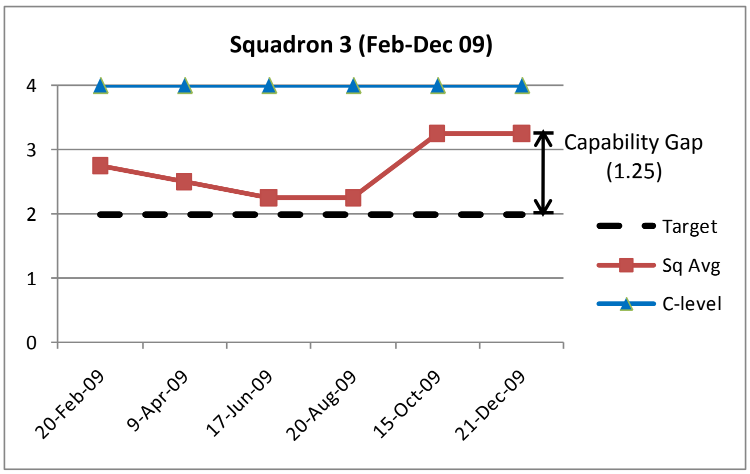


Figure 13. Plot of Notional SORTS Scores for Squadron 3

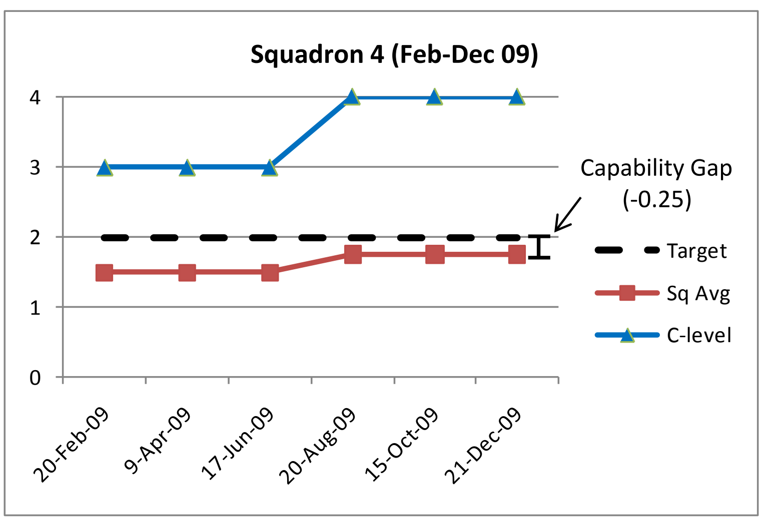


Figure 14. Plot of Notional SORTS Scores for Squadron 4

The commander's team realized they had more visibility into the overall health of the squadrons by looking at the average SORTS scores in addition to the C-level. For Squadron 3, the C-level remained constant at 4 throughout the entire time period, but the average revealed the fluctuation throughout the time period. For Squadron 4, the trend for the C-level actually mirrored that of the squadron average (both started getting worse between June and August), but it still did not adequately capture Squadron 4's overall health. In this case, the squadron average was always below the target value C-2, which revealed that the overall health of Squadron 3 was worse than that of Squadron 4. Therefore, the commander's team recommended doing a CPI event on Squadron 3 before working on Squadron 4. The commander, who saw the logic in the approach, approved the team's recommendation.

V. Recommendations & Conclusion

Summary

In chapters 1 and 2 of this paper, the reader was introduced to the concepts of continuous process improvement, metric development, and regression analysis. In chapter 3, these concepts were fused to produce a methodology for improving the bottom line of an organization by improving its weakest performance areas. The usefulness of this methodology was demonstrated through practical application to ACC in chapter 4.

Recommendations for Future Study

The key performance indicators analyzed in this paper are not all-inclusive. For the ACC case study, which can be applied to any MAJCOM in the Air Force, scores from other readiness reporting systems can serve as potential readiness indicators. The idea of using DRRS and ART scores was introduced in Chapter 3. Another set of metrics worthy of examination are Unit Compliance Inspection (UCI) scores. UCIs are conducted to assess mission areas that are critical to the health and performance of an organization, and a unit's failure to comply with these areas could result in legal liabilities, penalties, or mission impact. Therefore, it seems logical to conclude that a non-compliant unit is not ready to perform its mission, and hence UCI scores could be used to assess readiness.

Since SORTS scores are fairly subjective, it may be worthwhile to compare SORTS P ratings for individual squadrons versus the manning levels for the same squadrons during those months. This would provide insight into the fidelity of the SORTS scale by checking the consistency with which the ratings are currently being applied.

Finally, it may be beneficial to perform the regression and trends analysis on aviation and support units separately. Since a fighter squadron has a very different mission from a medical squadron, for example, each unit would likely use different definitions for mission impact and would assess their readiness accordingly. This would likely result in a disparity between their respective scores, which would essentially appear as though they are using two completely different scales. Studying the two types of units separately may potentially improve the fidelity of both models.

Other Recommendations

The following recommendations are intended to overcome some of the limitations that were mentioned in Chapter 4 of this paper. First, the fact that ACC reports SORTS scores for aviation and support units on an alternating bi-monthly basis, coupled with the issue that SORTS data are not archived on the SORTS website, imposed a limitation on the amount of data that was available for this study. Therefore, it is recommended that all SORTS and ART data be archived on its website for easy retrieval. In the meantime, it would be helpful if ACC would report all SORTS scores every month until the website is updated. In addition, functionality should be added that allows a user to produce customized reports.

There were also limitations to performing regression analysis in this study. Since ORI scores are only reported at the wing level and SORTS scores are only assessed at the squadron level, these scores were not directly comparable. One possible option for overcoming this limitation would be to aggregate squadron SORTS data into an overall wing score. This would allow both SORTS and ORI scores to be compared at the wing level. Another option would be to assess ORIs at the squadron level, which would also allow for direct comparison of both scores. Having this data readily accessible on the respective websites would also be beneficial.

Another limitation encountered during this research was the current method for determining overall SORTS scores. Currently, a unit’s overall SORTS C-level is the maximum of its P, T, S, R scores. As we saw in Chapter 4, however, the maximum score is not necessarily representative of a unit’s overall health. Therefore, it is recommended that the method for determining overall SORTS C-levels should become something besides the maximum of the P, T, S, R scores. The workaround used in this study involved taking the average across the four scores, but this is certainly not the only option.

The AFSO21 tool kit is powerful, flexible, and extremely useful. It is critical that it should be used today in a way that will help the Air Force do its mission better tomorrow.

Appendix A: Abbreviations

ACC – Air Combat Command
ACC/A3 – Air Combat Command Directorate of Operations
ACC/A9 – Air Combat Command Directorate of Analyses, Lessons Learned & AFSO21
AEF - Air Expeditionary Force
AFI – Air Force Instruction
AFPD – Air Force Program Directive
AFSO21 – Air Force Smart Operations for the 21st Century
ART - AEF (Air Expeditionary Force) Unit Type Code (UTC) Status Reporting Tool
BPR – Business Process Reengineering
C - Category
CAF – Combat Air Force
CJCS – Chairman of the Joint Chiefs of Staff
COCOM – Combatant Commander
COMACC – Commander of Air Combat Command
CPI – Continuous Process Improvement
CSAF - Chief of Staff United States Air Force
DMAIC – Define, Measure, Analyze, Improve, Control
DoD – Department of Defense
DRRS – Defense Readiness Reporting System
IG – Inspector General
KPI – Key Performance Indicator
LSS – Lean Six Sigma
MOE – Measure of Effectiveness
MOP – Measure of Performance
NMS – National Military Strategy
ORI – Operational Readiness Inspection
OSD – Office of the Secretary of Defense
P - Personnel
R - Equipment Condition
S - Supplies/Equipment
SA&D – Strategic Alignment and Deployment
SIPRNet – Secret Internet Protocol Router Network
SORTS – Status of Resources and Training Reporting System
T - Training
TOC – Theory of Constraints
TQM – Total Quality Management
UMD – Unit Manning Document
UTC – Unit Type Code

Appendix B: Blue Dart

AFSO21: How do we make it work?

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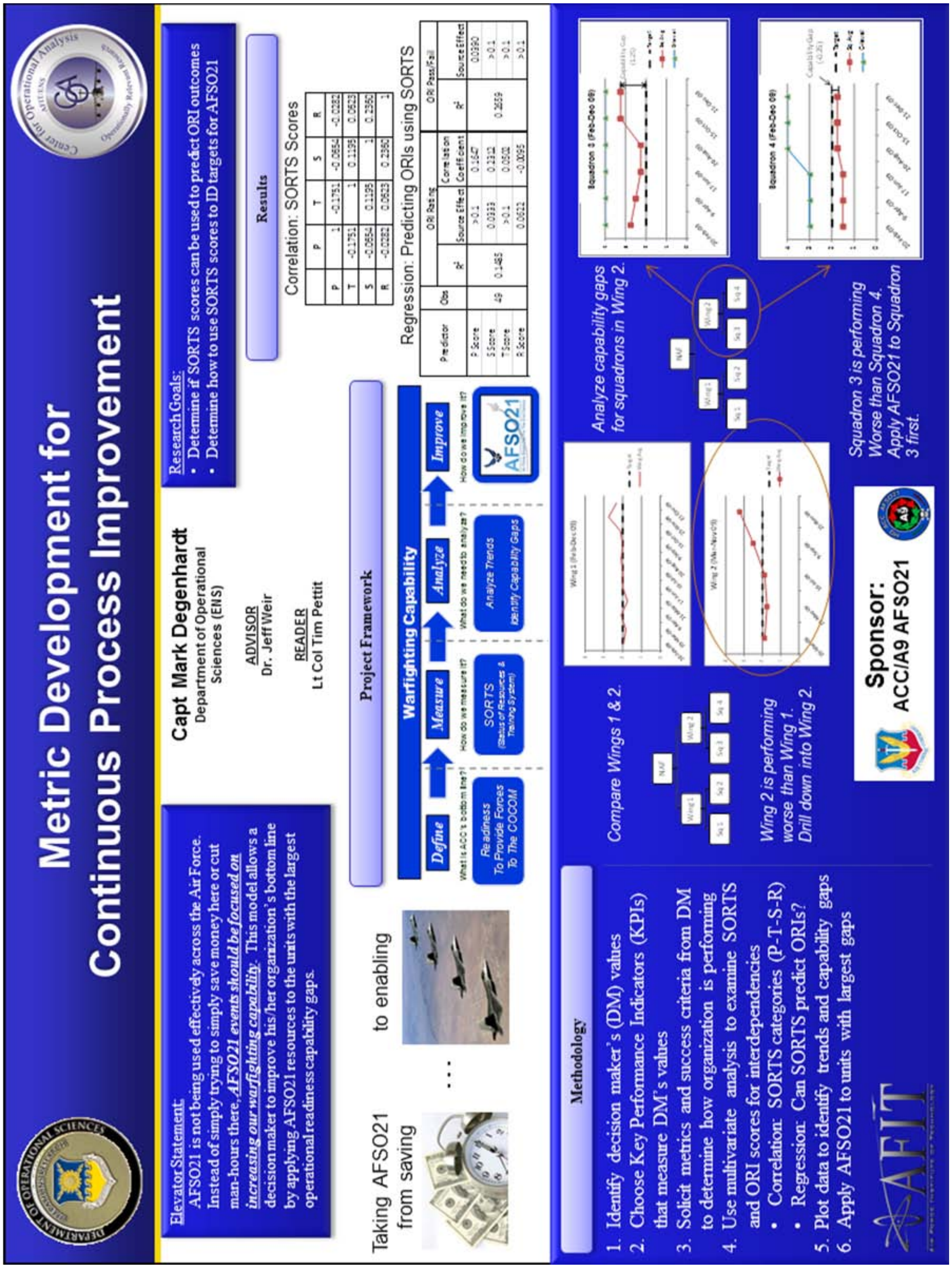
Air Force Smart Operations for the 21st Century (AFSO21) is not currently being used as effectively as it could be across the Air Force. Thanks to the Air Force website, Air Force Times, and other media sources, we hear about various success stories where processes are streamlined, hundreds of man-hours are cut, and thousands of American tax dollars are saved. These are obviously very good things, but we need to ask ourselves what effect these scattered (and somewhat random) improvements have on the core mission? For example, did streamlining an F-16 tire manufacturing process to double the output capacity from four to eight tires per day really benefit the Air Force? Did it enable us to put more planes on the runway and into the fight? How was this particular process chosen? What was the reason for doing the event? *Was* there a reason? Or was the unit directed to “do an AFSO21 event on something” just to meet a quota?

All of these queries lead to one underlying question: how do we use AFSO21 to go from creating OPR fodder to truly making a difference for the Air Force? This can be compared to a medical patient with a minor but lingering illness asking a doctor how to get better. The doctor would probably tell the patient that they need to stop trying to treat the symptoms and start treating the root causes of their problem. For the Air Force, this means that, instead of trying to simply save money here or cut man-hours there, AFSO21 tools should be aimed at solving the bigger issue of improving the Air Force's bottom line. For a business, the bottom line is profit. Therefore, to improve their bottom line is to increase profit. However, since the Air Force is a non-profit government entity, it can be argued that our bottom line is mission performance. In other words, we need to use these tools to "fly, fight and win" *better*. As it turns out, the Air Force Institute of Technology (AFIT) has done some research that addresses this very issue.

Through its research, AFIT developed a methodology to identify specific target areas where continuous process improvement, i.e., AFSO21, should be applied to improve the bottom line of an organization. The first step in this process is to engage the decision maker to solicit the key performance indicators (KPIs) that best reflect the organization's mission. The goal for this step is to make a list of the answers to the "why are we here" question. The second step is to use and/or develop appropriate metrics based on those KPIs to measure how well the organization is doing its mission today. The third step is to capture the trends of those KPIs over time to see if the organization is getting better or worse. The fourth and final step is to identify the largest performance capability gaps in order to determine where AFSO21 resources should be applied to get "the most bang for the buck". The result of this process should give the decision maker a clear snapshot of his/her organization's current ability to perform its mission. This, in turn, gives him/her the ability to improve the bottom line by improving the weakest areas.

The AFSO21 tool kit is powerful, flexible, and extremely useful. We should be using it today in a way that will make the Air Force do its mission better tomorrow.

Appendix C: Storyboard



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Vita

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His first assignment was at Los Angeles AFB as an acquisitions officer in November 2002. In October 2005, he was assigned to the 4^{th} Space Launch Squadron at Vandenberg AFB, California where he served as flight commander for Delta IV operations. In August 2009, he entered the Graduate School of Engineering and Management at the Air Force Institute of Technology. Upon graduation, he will be assigned to Force Management Policy Division of the Air Force Headquarters at the Pentagon.

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14. ABSTRACT
Air Force Smart Operations for the 21st Century (AFSO21) is not currently being used as effectively as it could be across the Air Force. Instead of trying to simply save money here or cut man-hours there, AFSO21 tools should be used to help the Air Force "fly, fight and win" *better*. The Air Force Institute of Technology (AFIT) has developed a methodology to identify specific target areas where continuous process improvement, i.e., AFSO21, can be applied to improve the bottom line of an organization. The first step of this process is to solicit the key performance indicators (KPIs) that best reflect the organization's mission. The second step is to use and/or develop metrics based on those KPIs to measure the organization's mission performance today. The third step is to capture the trends of those KPIs over time to see if the organization is getting better or worse. The final step is to identify the largest performance capability gaps in order to determine where AFSO21 resources should be applied to get "the most bang for the buck". The result of this process should give the decision maker the ability to improve the bottom line of an organization by improving its weakest areas. Air Combat Command is used as a case study for the application of this methodology.

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